BASSTEGG
(Bay Area Simplified Simulation of Travel, Energy and Greenhouse Gases)

Sketch Planning Charrette/GIS Models for Predicting Household Vehicle Miles of Travel (VMT) and Greenhouse Gas (CO_2) Emissions

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Abstract

With the increased interest in the interactions of land use and transportation and their related impacts on global warming, there is now a warranted need for improved and quicker techniques for simulating mobile source based, regional and sub-regional greenhouse gas emissions. The Bay Area Simplified Simulation of Travel, Energy and Greenhouse Gases (BASTEGG) is a GIS-based tool for calculating automobile availability, vehicle usage, fuel consumption, and greenhouse gas emissions, by each household within the San Francisco Bay Area at the neighborhood level. There are three component models in the BASSTEGG, simulating auto ownership levels, vehicle usage levels, and carbon dioxide emissions. Socio-economic and relative transit-to-highway accessibility data at the travel analysis zone level is used to predict the distribution of households by vehicle availability level. Cross-classification models of vehicle miles of travel per household (VMT/HH) are applied based on urban density levels, workers in household levels, income levels, and vehicle availability levels. Lastly, emissions per mile models, based on California Air Resources Board's EMFAC models for various forecast years, are used to convert VMT per household into on-road, mobile source greenhouse gas emissions per household. The BASSTEGG model is intended to be used in land use alternatives scenario testing at the regional level, and by city planners interested in the VMT and greenhouse gases produced by residents of their communities.

Introduction

As the regional metropolitan planning organization (MPO) for the nine-county San Francisco Bay Area, the Metropolitan Transportation Commission (MTC) is responsible for maintaining and applying future year travel forecast models to support planning for the development and operation of transportation facilities. In addition,

MTC is responsible for regularly updating the Regional Transportation Plan (RTP), a comprehensive design for the development of mass transit, highway, airport, seaport, railroad, bicycle and pedestrian facilities

With the increased interest in the interactions of land use and transportation and their related impacts on global warming, there is now a warranted need for improved and quicker techniques for simulating mobile source based, regional and sub-regional greenhouse gas emissions. The Bay Area Simplified Simulation of Travel, Energy and Greenhouse Gases (BASTEGG) is a GIS-based tool for calculating automobile availability, vehicle usage, fuel consumption, and greenhouse gas emissions, by each household within the San Francisco Bay Area at the neighborhood level. There are three component models in the BASSTEGG, simulating auto ownership levels, vehicle usage levels, and carbon dioxide emissions. Socio-economic and relative transit-to-highway accessibility data at the travel analysis zone level is used to predict the distribution of households by vehicle availability level. Cross-classification models of vehicle miles of travel per household (VMT/HH) are applied based on urban density levels, workers in household levels, income levels, and vehicle availability levels. Lastly, emissions per mile models, based on California Air Resources Board's EMFAC2007 (version 2.3, November 1, 2006) model for various forecast years, are used to convert VMT per household into on-road, mobile source greenhouse gas emissions per household. The BASSTEGG model is intended to be used in land use alternatives scenario testing at the regional level, and by city planners interested in the VMT and greenhouse gases produced by residents of their communities.

BASSTEGG could calculate household VMT based, regionwide, community-wide greenhouse gas emission information for Bay Area local governments. By using BASSTEGG, a local government staff member would be able to use jurisdiction-level socio-economic data and estimate household CO_2 emission inventories for individual communities. Local government staff can use this policy-relevant data to track a jurisdiction's climate protection progress over time; compare their activity data or "indicators" to those of neighboring jurisdictions; develop and evaluate greenhouse gas control measures; and help build their all sources community-wide emissions inventory.

Background and Need

Governor Schwarzenegger signed Executive Order # S-3-05 on June 1, 2005. The Executive Order established greenhouse gas targets:

- By 2010, Reduce to 2000 Emission Levels
- By 2020, Reduce to 1990 Emission Levels
- By 2050, Reduce to 80 percent Below 1990 Levels

In 2006 California enacted landmark greenhouse gas legislation -- AB 32, the Global Warming Solutions Act of 2006. The law requires California to reduce its total greenhouse gas emissions to 1990 levels by 2020, which represents about a 25% percent reduction from current levels. Achieving these reductions will be a challenging

task, especially since California's population is expected to grow from about 38 million in 2007 to 60 million in 2050.[1]

The California Air Resources Board (ARB or Board) is the lead agency for implementing AB 32, which set the major milestones for establishing the program. ARB met the first milestones in 2007: developing a list of discrete early actions to begin reducing greenhouse gas emissions, assembling an inventory of historic emissions, establishing greenhouse gas emission reporting requirements, and setting the 2020 emissions limit.

ARB was also responsible to develop a Scoping Plan outlining the State's strategy to achieve the 2020 greenhouse gas emissions limit. The Proposed Scoping Plan, developed by ARB in coordination with the Climate Action Team (CAT), proposes a comprehensive set of actions designed to reduce overall greenhouse gas emissions in California, improve the environment, reduce dependence on oil, diversify energy sources, save energy, create new jobs, and enhance public health. The Scoping Plan was presented and approved by the ARB Board at its meeting in December 2008 with the included measures to be developed over the next two years and be in place by 2012.

Local governments are essential partners in achieving California's goals to reduce greenhouse gas emissions. They have broad influence and, in some cases, exclusive authority over activities that contribute to significant direct and indirect greenhouse gas emissions through their planning and permitting processes, local ordinances, outreach and education efforts, and municipal operations. Many of the proposed measures to reduce greenhouse gas emissions rely on local government actions.[2]

A helpful tool to local governments in climate protection is an assessment, or inventory, of their community's greenhouse gas emissions. Inventories can be used by policy makers to understand how distinct sectors and activities contribute to climate change. Using the information provided in a community-wide greenhouse gas emission inventory, policymakers can develop policies to reduce greenhouse gas emissions from their community. The inventory also allows a community to track its long term progress in reducing greenhouse gas emissions.

As of January 2008, approximately 40 Bay Area jurisdictions have developed or are in the process of developing a community-wide greenhouse gas emission inventory.

Specifically, in developing residential VMT sourced community-wide greenhouse gas emission inventories, many local governments face a common set of challenges. During this inventory process, most local governments and their staff must:

1. Allocate appropriate staff time or contractor resources, recent inventory development projects have cost local jurisdictions on the order of tens of thousands of dollars per jurisdiction;

2. Experience a steep learning curve with regards to inventory protocol principles and practices, activity and emission data formats, and data sources (when expertise is not in-house);
3. Make data requests to multiple data providers who are often not prepared or staffed to field such requests and as a result sometimes provide inconsistent responses form year to year or government to government; and
4. Face the above challenges again years later when updating the inventory, Thus, which point staff may have turned over; often when staff has turned over, much of the institutional knowledge, and even the documentation on inventory development, is lost and must be recreated.

Some local governments, such as those in Sonoma and Alameda counties, have been able to save time and money in inventory development by aggregating their data requests. Consolidation of data requests also makes data processing easier for data providers. Data providers often have to run a data query for all local governments in a given county to respond to a request from one single jurisdiction. Submitting data requests and responding to requests in a consolidated manner contributes to consistent request formats and consistent response formats, making the data easier to understand and use for local governments.[3]

Model Application and Results

The Bay Area Simplified Simulation of Travel, Energy and Greenhouse Gases (BASTEGG) can be used by local jurisdictions to independently calculate CO_2 and greenhouse gas emission inventories at a low cost and in an easy manner. There are three component models in the BASSTEGG:

1. Models simulating auto ownership levels,
2. Models simulating vehicle usage levels, and
3. Application of carbon dioxide emission factors (generated from ARB's EMFAC2007 model) to estimate CO_2 emission inventories.

In 2000, the Metropolitan Transportation Commission (MTC) launched its fifth travel survey effort in the nine-county Bay Area and the result was the Bay Area Travel Survey 2000, or BATS2000. BATS2000 collected travel information from residents of the nine-county Bay Area for weekday and weekend travel both inside and outside of the region.[4]

From the BATS2000 survey, the Public Use Microdata Samples (PUMS) and data from the 2006 American Community Survey (for the Bay Area), a set of cross-classification models to calculate vehicle miles of travel per household or VMT/HH were developed. These models were applied based on urban density levels, workers in household levels, income levels, and vehicle availability levels to complete the first two components of BASSTEGG.

The third component of BASSTEGG, which calculates CO_2 vehicle emission factors, generates exhaust (tailpipe) emission factors from EMFAC2007, version 2.3, November 1, 2006. To estimate the needed emission factors, EMFAC2007 is run in burden mode for a calendar year 2007 and emission factors are derived from the resulting on-road mobile source emission inventory for the Bay Area region. (By dividing the exhaust emissions by the corresponding VMT) The EMFAC2007 emission factors are applied to the various VMT per household values for the cross-classified socio-economic, area type and county results to estimate mass emissions.

Conclusions and Next Steps

Tables S.1 through S.10 represent the VMT per household output from the cross-classification of the BATS2000 data. General observations include:

1. Higher VMT per household levels in lower density land-use areas
2. Lower VMT per household levels in higher density land-use areas
3. Higher VMT per household levels in higher income areas
4. Lower VMT per household levels in lower income areas
5. Higher VMT per household levels in homes with more vehicles available
6. Lower VMT per household levels in homes with less vehicles available
7. Higher VMT per household levels in homes with more workers
8. Lower VMT per household levels in homes with less workers
9. Higher VMT per household levels in more affluent Bay Area counties
10. Lower VMT per household levels in less affluent Bay Area counties

Table S.11 and figures 1 and 2 display EMFAC2007 emission factors and CO_2 emissions per household estimates for tables S.3 and S.7 respectively. In figure 1, a regional average exhaust emission factor was applied to calculate the results and in figure 2, county specific exhaust emission factors were applied.
With BASSTEGG, San Francisco Bay Area local community planners estimate household VMT-based CO_2, greenhouse gas emission inventories and alter current socio-economic and land use conditions to calculate potential emission benefits and/or impacts. Planners can complete these estimates independently with a minimal level of effort. In addition, these calculations and the results can provide very useful information to decision-makers.

One deficiency with BASSTEGG is that the CO_2 emission estimates are household based only and emissions due to non-home based trip, commercial vehicle travel, municipal vehicle travel and inter-regional travel are not accounted for in this model. Future improvements to BASSTEGG would be directed at including other non-household based travel in its CO_2 emission inventory estimates.

Table S.1
VMT per Household by Workers in Household by Density Level
Bay Area Travel Survey 2000, Regional Total

Density Level	Zero-Worker Households	Single-Worker Households	Multi-Worker Households	Total Households
Rural	26.6	47.3	71.9	53.9
Rural-Suburban	16.3	37.7	71.2	51.1
Suburban - Dispersed	18.2	35.8	59.5	44.1
Suburban - Dense	12.2	28.9	48.6	35.4
Urban	9.3	22.5	41.4	29.3
Urban Core	5.0	15.1	29.7	19.3
Total	14.0	28.6	50.8	36.4

Table S.2
Households by Workers in Household by Density Level
Bay Area Travel Survey 2000, Regional Total

Density Level	Zero-Worker Households	Single-Worker Households	Multi-Worker Households	Total Households
Rural	26,649	57,189	61,763	145,601
Rural-Suburban	18,129	40,669	58,089	116,887
Suburban - Dispersed	113,479	283,924	342,624	740,027
Suburban - Dense	90,845	253,376	282,393	626,614
Urban	56,591	216,847	216,300	489,738
Urban Core	46,138	168,478	132,537	347,153
Total	351,830	1,020,484	1,093,706	2,466,020

Table S.3
VMT per Household by Income Level by Density Level
Bay Area Travel Survey 2000, Regional Total

Density Level	Low Income Households	Low-Moderate Income Households	Moderate-High Income Households	High Income Households	Total Households
Rural	26.4	49.3	60.1	71.9	53.9
Rural-Suburban	20.3	43.8	55.6	66.0	51.1
Suburban - Dispersed	17.7	36.1	53.1	54.7	44.1
Suburban - Dense	14.6	31.7	40.1	48.0	35.4
Urban	15.2	28.3	35.2	40.0	29.3
Urban Core	7.6	16.1	20.5	37.6	19.3
Total	15.2	31.2	42.4	50.8	36.4

Table S.4
Households by Income Level by Density Level
Bay Area Travel Survey 2000, Regional Total

Density Level	Low Income Households	Low-Moderate Income Households	Moderate-High Income Households	High Income Households	Total Households
Rural	27,886	38,056	41,568	38,091	145,601
Rural-Suburban	16,262	27,425	37,846	35,355	116,887
Suburban - Dispersed	107,504	191,145	223,655	217,723	740,027
Suburban - Dense	110,208	166,197	192,295	157,913	626,614
Urban	118,279	134,160	152,543	84,756	489,738
Urban Core	78,032	108,517	96,880	63,724	347,153
Total	458,171	665,501	744,785	597,563	2,466,020

Table S.5
VMT per Household by Vehicles in Household by Density Level
Bay Area Travel Survey 2000, Regional Total

Density Level	Zero-Vehicle Households	Single-Vehicle Households	Multi-Vehicle Households	Total Households
Rural	1.1	27.6	64.6	53.9
Rural-Suburban	1.4	28.2	60.1	51.1
Suburban - Dispersed	2.1	23.3	54.6	44.1
Suburban - Dense	1.4	21.6	46.2	35.4
Urban	1.2	20.0	42.9	29.3
Urban Core	0.8	19.1	38.4	19.3
Total	1.2	21.7	50.3	36.4

Table S.6
Households by Vehicles in Household by Density Level
Bay Area Travel Survey 2000, Regional Total

Density Level	Zero-Vehicle Households	Single-Vehicle Households	Multi-Vehicle Households	Total Households
Rural	3,314	36,425	105,862	145,601
Rural-Suburban	5,389	23,218	88,280	116,887
Suburban - Dispersed	25,808	206,475	507,744	740,027
Suburban - Dense	45,763	193,450	387,400	626,614
Urban	52,850	194,732	242,156	489,738
Urban Core	104,151	139,911	103,092	347,153
Total	237,275	794,210	1,434,535	2,466,020

Table S.7
VMT per Household by County of Residence by Density Level
Bay Area Travel Survey 2000, Regional Total

Density Level	San Francisco Households	San Mateo Households	Santa Clara Households	Alameda Households	Contra Costa Households
Rural	--	70.4	50.0	50.3	56.2
Rural-Suburban	27.7	64.9	54.5	47.9	45.5
Suburban - Dispersed	31.9	44.1	42.4	39.9	47.0
Suburban - Dense	20.1	36.7	37.2	34.7	32.1
Urban	28.1	30.8	33.2	24.2	34.0
Urban Core	17.2	35.9	29.0	19.5	28.8
Total	19.6	39.5	37.8	32.1	42.7

Table S.7 (continued)
VMT per Household by County of Residence by Density Level
Bay Area Travel Survey 2000, Regional Total

Density Level	Solano Households	Napa Households	Sonoma Households	Marin Households	Regional Households
Rural	70.3	42.0	51.7	47.2	56.2
Rural-Suburban	65.1	37.5	49.8	41.5	45.5
Suburban - Dispersed	52.3	43.1	50.6	35.0	47.0
Suburban - Dense	33.8	27.5	37.9	22.9	32.1
Urban	48.9	42.2	23.8	--	34.0
Urban Core	--	--	55.3	--	28.8
Total	50.1	39.9	48.4	36.4	36.4

Table S.8
Households by County of Residence by Density Level
Bay Area Travel Survey 2000, Regional Total

Density Level	San Francisco Households	San Mateo Households	Santa Clara Households	Alameda Households	Contra Costa Households
Rural	--	12,745	8,804	12,964	18,773
Rural-Suburban	2,173	7,667	24,953	6,879	31,970
Suburban - Dispersed	1,434	69,030	102,569	154,253	182,696
Suburban - Dense	6,134	72,598	252,250	137,991	80,028
Urban	66,981	73,705	163,270	157,234	23,977
Urban Core	252,977	18,357	14,019	54,045	6,685
Total	329,699	254,103	565,865	523,366	344,129

Table S.8 (continued)
Households by County of Residence by Density Level
Bay Area Travel Survey 2000, Regional Total

Density Level	Solano Households	Napa Households	Sonoma Households	Marin Households	Regional Households
Rural	12,321	13,343	52,110	14,540	145,601
Rural-Suburban	12,681	2,989	22,254	5,321	116,887
Suburban - Dispersed	68,144	20,654	66,363	74,883	740,027
Suburban - Dense	36,034	7,402	28,271	5,906	626,614
Urban	1,222	1,014	2,334	--	489,738
Urban Core	--	--	1,071	--	347,153
Total	130,403	45,402	172,403	100,650	2,466,020

Table S.9
VMT per Household by Workers in Household by Vehicles in Household
Bay Area Travel Survey 2000, Regional Total

Vehicles in Household	Zero-Worker Households	Single-Worker Households	Multi-Worker Households	Total Households
Zero-Vehicle	0.4	1.5	2.0	1.2
Single Vehicle	13.2	23.8	23.9	21.7
Multiple Vehicles	26.7	41.9	56.8	50.3
Total	14.0	28.6	50.8	36.4

Table S.10
Households by Workers in Household by Vehicles in Household
Bay Area Travel Survey 2000, Regional Total

Vehicles in Household	Zero-Worker Households	Single-Worker Households	Multi-Worker Households	Total Households
Zero-Vehicle	88,084	115,627	33,564	237,275
Single Vehicle	159,761	491,889	142,561	794,210
Multiple Vehicles	103,985	412,968	917,581	1,434,535
Total	351,830	1,020,484	1,093,706	2,466,020

Table S.11
San Francisco Bay Area
2007 Summer Exhaust CO_2 Emission Rates
Emissions in Tons Per Day

			CO_2 Exhaust*				
County	**Population**	**Total VMT***	**All Vehicles**				
Alameda	1,128,440	38,335	23.30	551.39		1.216	
Contra Costa	771,016	25,779	15.20	534.90		1.179	
Marin	206,192	6,188	3.72	545.37		1.202	
Napa	140,103	4,522	2.72	545.68		1.203	
San Francisco	408,765	12,479	7.67	557.59		1.229	
San Mateo	575,291	19,441	10.39	484.83		1.069	
Santa Clara	1,260,650	40,259	23.03	518.95		1.144	
Solano	207,438	7,201	4.38	551.79		1.216	
Sonoma	339,051	10,546	6.35	546.24		1.204	
Total	5,036,946	164,750	96.76	532.80		1.175	
				in grams per mile		in pounds per mile	

*in thousands
EMFAC2007 V2.3 Nov 1 2006 ** WIS Enabled **

Figure 1

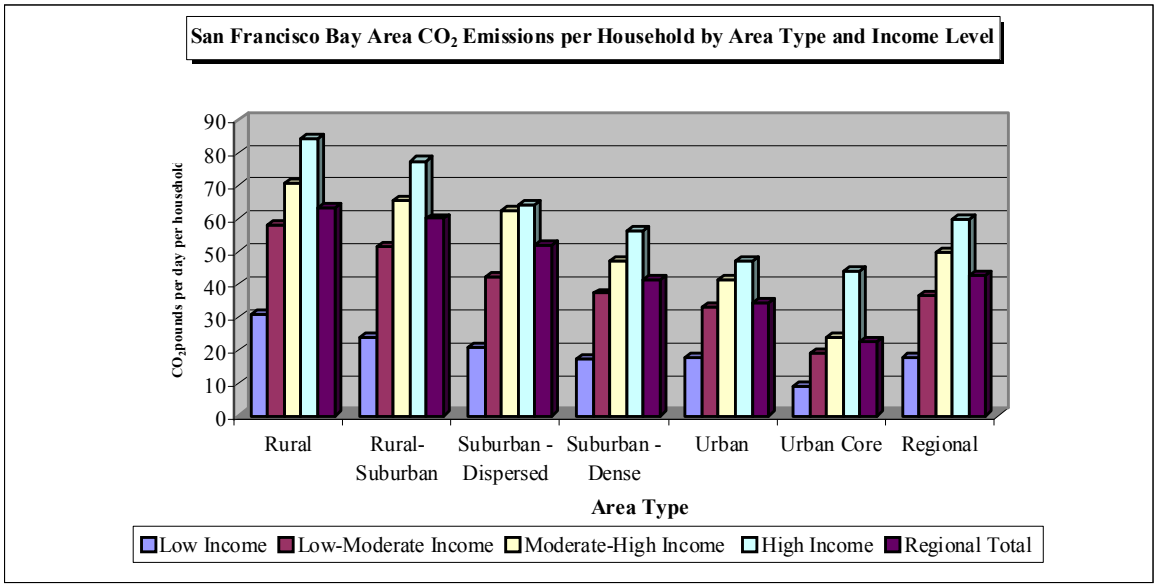
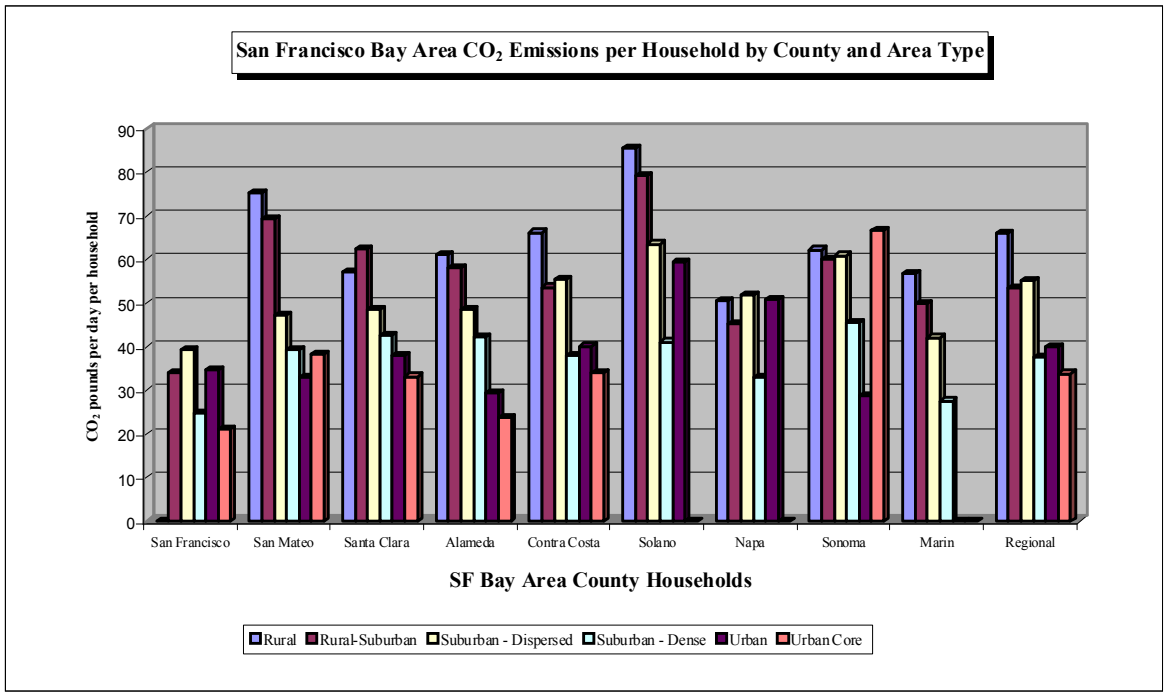


Figure 2



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